B.N.MANDAL UNIVERSITY ,MADHEPURA

Synopsis on

"ANALYSIS OF DIFFRACTION FROM PERIODIC STRUCTURES AND ITS APPLICATION IN ANTENNA DESIGN"

By:-

SHANKAR KUMAR

For

Ph.D Degree in Faculty of Science (Physics)

Under the Supervision

Of

Dr. Anil Kumar

Department of Physics

Associate Professor

R.J.M. College, Saharsa

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SYNOPSIS FOR Ph. D. DEGREE IN PHYSICS

FACULTY OF SCIENCE

1. TITLE OF THE RESEARCH

ANALYSIS OF DIFFRACTION FROM PERIODIC STRUCTURES AND ITS APPLICATION IN ANTENNA DESIGN

2. WORK PLAN

a. Purpose and Need of the Study

The study of electromagnetic diffraction from periodic structures and the utilization of these phenomena in antenna design are both timely and essential. Periodic structures, such as gratings, frequency-selective surfaces (FSS), electromagnetic band-gap (EBG) surfaces, and meta surfaces introduce rich behaviour in wave propagation. The most common phenomena are the diffraction orders, band-gaps, resonance phenomena, and scattering behaviours. Understanding and harnessing these phenomena can lead to enhanced antenna performance such as gain, bandwidth, scanning, mutual-coupling reduction, and miniaturization, beam-shaping and novel capabilities.

From a fundamental viewpoint, diffraction from periodic structures is a classical yet still evolving area—covering grating theory, band-structure of periodic media and scattering from multilayer periodic screens. The recent work on "Generalized space–time periodic diffraction gratings" highlights advanced diffraction phenomena beyond the simple spatial periodicity. Meanwhile, antennas increasingly demand compactness, multi-band/wideband operation, beam-steering, high integration with other systems (IoT, 5G/6G, mm-wave). Periodic structures become valuable design tools in the context such as periodic superstrates, ground-plane modifications, periodic feeding networks, or scanning arrays. Hence there is need for the study to relate these diffraction phenomena to practical antenna engineering: how periodic structures can be employed to shape radiation, reduce unwanted coupling, control surface-waves, implement scanning, etc. There is need to provide a structured

methodology for combining diffraction theory and antenna design, thereby bridging the gap between classical electromagnetic scattering theory and modern antenna design practice.

There is also need to optimization of periodic structure parameters for antenna use, mutual coupling in periodic antenna arrays, and integration at higher frequencies.

b. <u>Details of the Project with Chapterization</u>

The proposed structure for the full research project will contain the following chapters:-

Chapter1: In this part of the thesis Introduction will be presented. With the growth of wireless communications, antenna performance demands miniaturization, wide-band, scanning, high gain and the role of periodic structures.

Brief overview of diffraction, periodic structures, and antenna design challenges will also be described here.

Chapter 2: In this part of the thesis fundamentals of Diffraction and Periodic Structures will be presented. Review of electromagnetic wave theory with Maxwell's equations and boundary conditions will also be described. Mathematical modelling of periodic structures: e.g., Rigorous Coupled Wave Analysis (RCWA) for gratings will also be discussed.

Chapter 3: In this part of thesis review of periodic structures such as gratings, FSS, EBGs, meta surfaces will be made in antenna design.

Chapter 4: In this part of the thesis Theoretical and Numerical Methodology for Diffraction Analysis will be presented. The modal analysis, grating equation, and embedded eigen-mode analysis will also be presented.

Chapter 5: In this section of the thesis the designing of periodic structure for antenna enhancement will be made. As for instance the periodic superstrate for gain enhancement, FSS ground for mutual coupling reduction, periodic grating feed for scanning beam control will be studied.

In the initial state we will identify antenna baseline design without periodic structure and its performance metrics gain, bandwidth, radiation pattern, coupling will be

studied. In the second step we will define periodic structure geometry and parameters. After it the system will be combined and simulated results will be studied. Finally the limitations and the practical constraints will be studied.

Chapter 6: In this section of the thesis we will carry out a systematic parametric study so as to vary periodicity, element shape, substrate permittivity, superstrate height, orientation relative to antenna feed for desired antenna metrics such as gain, side-lobe level (SLL), bandwidth and efficiency.The results may be presented in the form of graphs/tables.

Chapter 7: In this last section of the thesis we will present discussion, Future Work and Conclusions

c. Methodology

The methodology for the research will be divided into different phases as given bellow:-

In the first phase literature survey will be done to gather classical diffraction theory for periodic structures such as gratings, multilayer stacks and periodic screens with its extension to electromagnetic periodic media. Then problems will be formulated,

Then the grating equation will be derived for diffraction orders such as for incident plane wave with wave-vector k_i, the allowed diffraction orders would satisfy the Floquet condition.

In the second phase the numerical simulation of the work will be done and the parametric optimization will be realized.

We will also discuss limitations such as fabrication tolerances, losses in periodic structures especially at mm-wave, complexity/weight of superstrates.

Finally we will consolidate findings into a coherent narrative: how diffraction theory of periodic structures supports improved antenna design; translation of theory → numerical modelling → antenna integration and optimization.

d. <u>References</u>

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I testify that I am in a position to devote time for this research work and undertake to complete this research work within specified maximum time limit.

Full signature of the research scholar

with date.

The candidate has undertaken to complete the research work under my supervision and guidance under the time limit.

Full signature of the supervisor

with date designation and address .